Automatic license plate detection based on colour gradient map

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Abstract

License plate detection plays a key role in traffic surveillance, speeding vehicles ticketing and vehicle detecting, and so on. However, most of the previous approaches to detect license plate experience difficulties in handling license plate with the uneven illuminations changes, complex background or tilted alignments. In this paper, we propose a method of license plate detection. License plate regions contain plate characters, frames and screws. First we propose to build the Colour Gradient Map (CGM) based on the colour gradient method. Then we perform the Niblack's method on the Colour Gradient Map (CGM) to retrieve the candidate license plate regions. Finally, we use the template matching to remove most of background noises. Experimental results show that this approach is robust and can be effectively applied to license plate detection.

Keywords: license plate detection, colour gradient, template matching

1 Introduction

With the rapid growth of city traffic, there is an urgent demand for intelligent transportation systems. The automatic license plate detection normally can be applied in various applications of intelligent transportation systems, such as traffic surveillance, speeding vehicles ticketing, vehicle detecting and stolen vehicle verification, and so on. As a result, automatic license plate detection is vital importance for intelligent transportation systems.

Although some papers (e.g. [1-12]) proposed some methods to detect the license plate, they have difficulties in detecting license plate in the situation, such as the un-even illuminations changes, complex background or tilted license plate. License plate regions contain plate characters, frames and screws. However, due to various cameras observation angles, the frames and screws will connect the plate characters with other regions, which is difficult to accurately detect the license plate. Therefore, we propose to build the Colour Gradient Map (CGM) (to be described in Section 3) based on the colour gradient method [13]. Then we perform the Niblack's method on the Colour Gradient Map (CGM) to retrieve the license plate regions.

The rest of this paper is organized as follows. Section 2 reviews the related work. Colour Gradient Map produced by our proposed method is described in Section 3. License plate detection is described in Section 4. Experimental results are presented and discussed in Section 5. Finally, in Section 6, we draw conclusion.

2 Related work

Current approaches on the license plate detection can be classified into three classes: Morphology-based methods, local features-based method, and Learning-Based methods.

The first class uses morphology-based methods [1-3] to detect license plate. Hsieh et al. [1] proposed a morphology-based method for detecting license plates. First, they used a morphology-based method to extract contrast features to search the desired license plates. Then, they applied a recovery algorithm for reconstructing a license plate if the plate is fragmented into several parts. Finally, they performed the license plate verification.

The second class uses the local features-based methods [4-7] to detect license plate. Zhou et al. [4] proposed a license plates detection method by principal visual word (PVW). They automatically discover the PVW characterized with geometric context. Given a new image, the license plates are extracted by matching local features with PVW. Due to the relatively expensive time cost in feature extraction, Zhou's approach is suitable for applications without strong requirement of real-time efficiency. Chen et al. [5] proposed a license plates detector based on a modified convolutional neural network (CNN) verifier. In the proposed verifier, a single feature map and a fully connected MLP were trained by examples to classify the possible candidates. They applied the Pyramid-based localization techniques to fuse the candidates and to identify the regions of license plates. Then, geometrical rules filtered out false alarms in license plate detection. Clemens Arth et al. [6] proposed a full-featured license plate detection system. They detect the license plate using the detector based on the

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AdaBoost approach. Detected license plates are segmented into individual characters by using a region-based approach.

The third class uses the learning-based methods [8-11] to detect license plate. Zhang et al. [9] proposes a license plate detection algorithm using both global statistical features and local Haar-like features. Classifiers using global statistical features are constructed firstly through simple learning procedures. Then the AdaBoost learning algorithm is used to build up the other classifiers based on selected local Haar-like features. Combining the classifiers using the global features and the local features, they obtain a cascade classifier. They construct the cascade classifier for license plate detection using both global and local features.

Different from the above three kinds of detecting license plate methods, some proposed other approaches recently. Lin et al. [12] proposed a license plate detection algorithm based on image saliency. The proposed algorithm consists of two parts. The first part segments out the characters on a license plate using an intensity saliency map with a high recall rate. The second part applies a sliding window on these characters to compute some saliency-related features to detect license plates.

3 Colour gradient map

License plate regions contain not only plate characters but also various adornments such as frames, screws. However, due to various cameras observation angles, the frames and screws will connect the plate characters with other regions, which is difficult to accurately detect the license plate. Therefore, we propose to build the Colour Gradient Map (CGM) based on the colour gradient method [13].

We use the colour gradient method to process the image. We use f to represent a colour image, R, G, B are the three colour bands of colour space RGB, respectively.

$$f(x,y)=\begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix}. \quad (1)$$

Then we define g_{xx}, g_{yy}, g_{xy} as follows:

$$g_{xx}=\left(\frac{\partial R}{\partial x}\right)^2+\left(\frac{\partial G}{\partial x}\right)^2+\left(\frac{\partial B}{\partial x}\right)^2, \quad (2)$$

$$g_{yy}=\left(\frac{\partial R}{\partial y}\right)^2+\left(\frac{\partial G}{\partial y}\right)^2+\left(\frac{\partial B}{\partial y}\right)^2, \quad (3)$$

$$g_{xy}=\frac{\partial R}{\partial x}\frac{\partial R}{\partial y}+\frac{\partial G}{\partial x}\frac{\partial G}{\partial y}+\frac{\partial B}{\partial x}\frac{\partial B}{\partial y}. \quad (4)$$

The gradient orientation in coordinate(x,y) is $\theta(x, y)$; the gradient magnitude in coordinate (x,y) is $F_\theta(x, y)$, they can be calculated by [13]:

$$\theta(x,y)=\frac{1}{2}\tan^{-1}\left(\frac{2g_{xy}}{g_{xx}-g_{yy}}\right), \quad (5)$$

$$F_\theta(x,y)= \sqrt{\frac{1}{2}[(g_{xx}+g_{yy})+(g_{xx}-g_{yy})\cos 2\theta+2g_{xy}\sin 2\theta]}. \quad (6)$$

We convolves the $f(x,y)$ with the averaging filters s via Equation (7) to get the mean colour image $fa(x,y)$.

$$s=\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad (7)$$

$$fa(x,y)=\begin{bmatrix} Ra(x,y) \\ Ga(x,y) \\ Ba(x,y) \end{bmatrix}, \quad (8)$$

$$cgm(x,y)=\begin{bmatrix} \|Ra(x,y)-F_\theta(x,y)\| \\ \|Ga(x,y)-F_\theta(x,y)\| \\ \|Ba(x,y)-F_\theta(x,y)\| \end{bmatrix}. \quad (9)$$

Because the colour gradient magnitude can represent the colour differences remarkably, we use the mean colour image subtract the gradient magnitude $F_\theta(x, y)$. As a result, we can get the Colour Gradient Map (CGM) via the Equation (9). The CGM can keep the license plate character regions completely and remove the colour difference, which can make the character edge details clearly. As a result, on the CGM the edges of character do not connect with the frames or screws. The Figure 1b is the CGM, compared with the original image Figure 1a, we can find that the license plate character has whole contour and do not connect with the screw or frames in the CGM.

a) b)

FIGURE 1 a) Original image, b) Colour Gradient Map on original image

4 License plate detection

License Plate detection is difficult due to uneven illuminations changes, complex background or tilted license plate. Niblack's method [14] presents a low-complexity method for automatically detecting text of any sizes, fonts, and alignments from images. However, Niblack's method relies on the local mean and standard deviation, which is sensitive to local abnormal intensity change. Because Colour Gradient Map (CGM) has remarkably made the character edge details clearly, it is suitable for the Niblack's method. Therefore, we perform the Niblack's method not on the original image but on the Colour Gradient Map (CGM). After performing the Niblack's method, we use the connected component analysis to remove the background noises.

4.1 NIBLACK'S METHOD

Niblack method can segment image into three different layers WonB, BonW and EonB. WonB refers to the White foreground on Black background. BonW refers to the Black foreground on the White background. The EonB refers to Edge on the Black background.

$$WonB(x,y)=\begin{cases}1 & f(x,y)>T_+\\ 0 & otherwise\end{cases}, \quad (10)$$

$$BonW(x,y)=\begin{cases}1 & f(x,y)<T_-\\ 0 & otherwise\end{cases}, \quad (11)$$

$$EonB(x,y)=\begin{cases}1 & T_-<f(x,y)<T_+\\ 0 & otherwise\end{cases}, \quad (12)$$

$$T_+(x,y)=\mu(x,y)+a\sigma(x,y), \quad (13)$$

$$T\_(x,y)=\mu(x,y)-a\sigma(x,y), \quad (14)$$

where Niblack threshold, T_+ and T_-, are calculated based on μ and σ, which are the mean and standard deviation in a neighbourhood window (h×w), and a is the constant which can be got by experiments. Figure 2 shows the WonB, BonW, EonB which is segmented by Niblack's method. Because the license plate license plates must be very salient to human visual observation, the license plate will always keep high contrast on the background. Therefore, the license plate will always identified by the WonB.

4.2 CONNECTED COMPONENT ANALYSIS

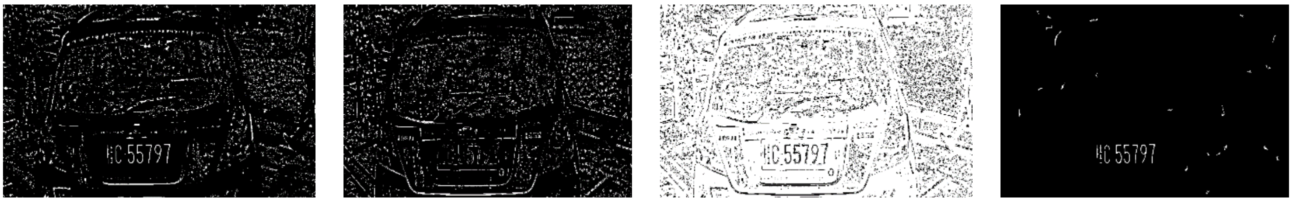
We perform the connected component analysis (CCA) on the WonB which is got by the Niblack's method. We use the following simple rules to perform the CCA on WonB.

Rule 1: We assume that the license plate will not occupy the whole image or occupy only small regions. As a result, we will remove some too small regions or too big regions.

Rule 2: Normally, the license plate will be surrounded by the frames, which will produce some backgrounds interference. So we will scan the WonB in horizontal line, and remove the lines which width is bigger than the one twentieth of the image width.

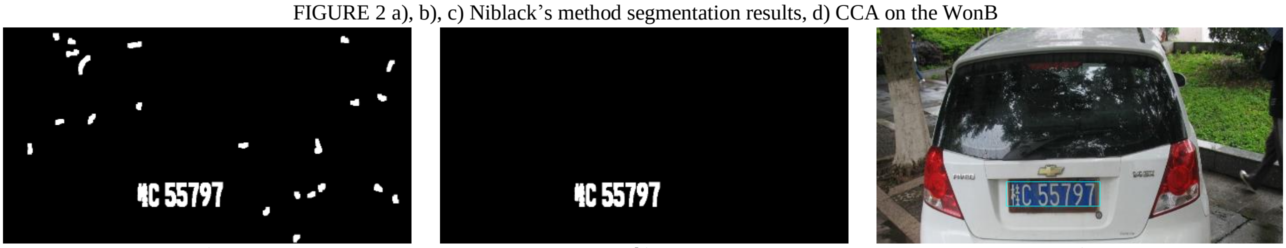
Rule 3: The license plate aligns in horizontal way, and generally the license plate contains at least five to seven characters. Therefore, we will remove the candidate regions when its width is bigger than the one tenth of the image width.

After the CCA on the WonB, we can remove some background interference, which is shown in Figure 2d.



a) b) c) d)

FIGURE 2 a), b), c) Niblack's method segmentation results, d) CCA on the WonB



a) b) c)

FIGURE 3 a) dilation morphological operation, b) template matching filtered results, c) final license plate detection results

4.3 CANDIDATE REGIONS FILTERED BASED ON TEMPLATE MATCHING

We use the matching of correlation [15] to realize the template matching. According to the matching of correlation [15], the spatial correlation can be obtained as the inverse Fourier transform of the product of the transform of one function times the conjugate of the transform of the other, which is shown in Equation (15).

$$f(x,y)\circ w(x,y)\Leftrightarrow F(u,v)H*(u,v), \quad (15)$$

where "∘" indicate the correlation and "*" indicate the complex conjugate.

Gonzalez at el. [15] proposed that given an image $f(x,y)$, the correlation is to find all places in the image that match a given template $w(x,y)$. The best match of $w(x,y)$ in $f(x,y)$ is the location of the maximum value. As a result, we can get the matching of correlation in the frequency domain.

a) b) c) d) e) f) g) h) i)

FIGURE 4 License Plate Detection Results

a) b) c) d)

FIGURE 5 Examples with Missed and False Detections

TABLE 1 Performance Comparison for License Plate Detection

	Total License Plate	Total Missed Textboxes	Total False Alarm	Detection Rate	False Alarm Rate	Detection Speed (Second/Per Image)
Zhou's Method	300	29	11	90.3%	3.7%	0.35
Hsieh's Method	300	36	9	88.0%	3.0%	0.43
Our Method	300	23	7	92.3%	2.3%	0.29

We find that license plate character is composed of Arabic number character and alphabetic character. As a result, we build a template set which include the 0-9 Arabic number character and A-Z alphabetic character. For some Chinese license plate, when we implement the template matching between the Chinese characters with the template set, the best matching value of Chinese character is far bigger than that of background noises. As a result, we can remove most of background noises based on the template matching. Before the template matching for the candidate regions, we perform the dilation morphological operation, which make the template matching performance more accurately. Figure 3 shows the whole process. In Figure 3a, we implement the dilation morphological operation on the CCA results. Figure 3b is the filtered results got by the template matching. Compared Figure 3b with Figure 3a, we can find that the background interference can be removed by the template matching.

5 Experiments and discussion

We have collected 300 license plate images. Our test data is composed of the Chinese license plate. Figure 4 shows the experimental results of license plate detection. In Figures 4(a-c), the license plate has different alignment. The detected results demonstrate that our approach is robust to detect such kind of license plate. The license plate which have light illumination changes Figures 4(d-f) are correctly detected. Figures 4 g and 4h demonstrate that our approach is robust to detect license plate with low resolution. Figure 4i shows that our method can detect the license plate when the license plate was blurring. These results also confirm that the proposed license plate detection algorithms are capable of handling the light uneven illuminations changes, complex background or tilted license plate.

Figure 5 shows some examples of misses or false detections. In Figure 5a the license plate character is too big to detect by our method. In Figure 5b, due to license plate regions is too dark, although our method can detect the license plate correctly, we also detect some other background regions. In Figure 5c, the license plate image is too blurred and the license plate character is too small, so our method cannot detect the license plate correctly. In Figure 5d, those false detected regions have similar texture as the text, meanwhile the license plate has serious stains which result the false detection. As a result, we can conclude that our method will cause some misses in license plate which have too big or small character, low contrast character and over-blurring character, and cause some false alarms which the license plate have serious stain.

We compare our proposed algorithm with [4] (Zhou's Method) and [1] (Hsieh's Method). Zhou's Method can automatically detect license plate. However, the computation cost is quite high owing to the computation cost in the feature extraction. Hsieh's Method proposed a morphology-based method for detecting license plates. However, they applied a recovery algorithm for reconstructing a license plate if the plate is fragmented into several parts, which will influence the detection speed. The detection speed of our method is much quicker than Zhou's Method and Hsieh's Method. The detection speed is indicated by the average processing time per image for the license plate detection tested on a PC with one Intel®Core™ 2 Quad CPU Q9400 2.66GHz. The comparison results can be seen in Table 1, which also indicates that our algorithm also has better detection rate and false alarm rate. The ground truth data are created manually.

6 Conclusions

A novel approach to detect license plate on the basis of the colour gradient map is proposed in the paper. Our experimental results and the comparisons with other methods show that our method is robust to detect license plate with the light uneven illumination changes, complex background or tilted alignments. The known limitation of license plate detection is that license plates with severe illumination changes cannot be detected. These issues will be addressed in our future research.

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